

## SURGICAL CONSIDERATIONS OF INTRATHORACIC ANEURYSMS OF THE AORTA AND GREAT VESSELS\*

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THE SURGICAL TREATMENT of intrathoracic aneurysms of the aorta and its major tributaries remains a difficult problem and, for the most part, unsatisfactory despite the remarkable advances in vascular surgery that have been made in recent years. This is exemplified by the fact that ideal surgical therapy, consisting of extirpation of the diseased part and restoration of normal function, has been applied to these lesions in rare instances. In this presentation, an effort is made to review and evaluate the various methods which have been proposed and employed in the surgical treatment of aneurysms of this region and to direct attention by illustrative case reports (Table I) to the indications and value of excisional therapy and aortorrhaphy.

The various procedures which have been used in the surgical treatment of these aneurysms may be conveniently classified into three major groups: (1) Those designed to promote thrombosis and fibrotic organization of the process by ligation, introduction of foreign material, or periarterial fibroblastic reaction; (2) endo-aneurysmorrhaphy; and (3) extirpation of the lesion with or without restoration of blood flow through the parent vessel.

### PROCEDURES WHICH PROMOTE THROMBOSIS

Various measures designed to induce thrombosis within an aneurysm have been

proposed and employed in order to achieve fibrotic organization of the process and thus prevent or delay the inevitable perforation of the sac. Matas<sup>37</sup> classified technics which assist in this effort by "1—diminishing the blood pressure, 2—retarding the velocity of circulation, 3—increasing the coagulability of blood, 4—provoking thrombus formation within the sac by agents which act directly on the aneurysmal tissues from within and from without." Efforts have long been made to devise ingenious therapeutic methods along these lines, including complicated dietetic, hygienic and medicinal regimens. After extensive trial, they have been discarded as ineffectual or unreliable. Even specific medicinal measures in syphilitic and mycotic aneurysms have usually proved ineffectual in controlling the fatal consequences of the process once the aneurysm is well developed. Certain other non-operative technics which have yielded only occasional good results by inducing thrombosis include refrigeration, prolonged compression of the sac, acupuncture<sup>34</sup> and the injection of sclerosing agents. Matas<sup>37</sup> has thoroughly reviewed these and other technics which have been used for this purpose, but they are now only of historical interest.

In the past 75 years, however, some progress has been made in the surgical management of aneurysms of the thoracic aorta and its great tributaries by inducing thrombosis, using one or more of the following methods:

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ligation, introduction of foreign material, or stimulation of periarterial fibrosis.

**Ligation.** Ligation of the artery at different points in relation to the aneurysm has been employed with the purpose of slowing or arresting the circulation in the sac in order to encourage thrombosis and eventual obliteration. The ligature may be applied to the artery on the proximal side of the aneurysm (Anel's operation), on the distal side (Brasdor's operation), or immediately above and below the aneurysm (Pasquin's operation). The latter is known as Antylus's operation if, in addition, the sac is evacuated and packed. These procedures have been employed for aneurysms involving both the thoracic aorta and its major branches. The recorded experience with these various forms of ligation was thoroughly reviewed by Matas,<sup>37</sup> in 1914, and subsequently by a number of others.<sup>22, 23, 31, 33, 47, 50</sup> On the basis of these experiences there seems to be general agreement that while occasional good results have been obtained from the procedure of distal ligation (Brasdor-Guinard method), it has not proved generally satisfactory, being associated with considerable risk and only moderate palliative value. Perhaps combined with other means of inducing thrombosis, such as wiring, distal ligation may have greater usefulness.<sup>8, 50</sup> Proximal ligation alone has also not provided very satisfactory results owing to the high incidence of cerebral complications, recurrence of the aneurysm as a consequence of development of anastomotic channels or incomplete occlusion by the ligature, and necrosis at the site of ligation with resultant hemorrhage. The latter complications are particularly well illustrated by the case reported by Tuffier<sup>55</sup> and by our Case 1. Tuffier's report, in 1902, is exceptionally noteworthy not only because his "case is unique in literature,"<sup>37</sup> but also because it reflects his courage and perspicacity. In this case of saccular aneurysm of the ascending aorta Tuffier applied

two catgut ligatures just distal to its neck, thus closing the feeder trunk. At this point he committed an error, the significance of which he realized later in that he did not remove the aneurysmal sac which was now empty and flaccid. He thought at the time of operation that the sac if left *in situ* would serve the dual purpose of preventing slippage of the ligature and of limiting hemorrhage if slippage did occur. The immediate course seemed satisfactory, but on the tenth day after operation the sac was observed to be gangrenous, and secondary hemorrhage ensued shortly after this, leading to death three days later. It may be observed that in our Case 1, which to our knowledge is the only case like Tuffier's, a similar fatal complication developed despite the effort to avert it by the use of an elastic ligature encased with polythene-dicetyl phosphate film to induce periarterial fibrosis.

Combined proximal and distal ligation has been employed successfully by a number of observers and provides definite advantages over the previously mentioned methods of ligation. In most instances where this is possible, permitting complete control of blood flow into the sac, it would seem preferable to extend the operation further and excise the aneurysm, or if this is not feasible, evacuate the clot.

**Introduction of Foreign Material.** Numerous materials have been introduced into aneurysms in order to promote coagulation of the blood, and of these, wire of various types has had the widest and most successful application. In 1865, Moore<sup>41</sup> inserted and left lengths of silver wire in a thoracic aneurysm in order to induce clot formation and Corradi,<sup>14</sup> in 1879, added to this method the passage through the wire of a Galvanic current. The Moore-Corradi electrolysis method enjoyed some popularity for several decades, but the results were in general not impressive. In order to avoid some of the difficulties involved in handling the wire and to obtain accurate insertion into the



aneurysm, Colt,<sup>12</sup> in 1903, devised a small wire umbrella which, after insertion through a cannula, expanded inside the aneurysm. Using Colt's method, Borrie and Griffin<sup>8</sup> have recently reported satisfactory results in five of nine cases of syphilitic aneurysm of the thoracic aorta and its branches.

The Moore-Corradi method was modified in 1938 by Blakemore and King,<sup>7</sup> who devised an accurate means of electrothermic coagulation of aneurysms. A deposit of

polythene plastic films in syphilitic aneurysms of the thoracic aorta, with apparent benefit.

Results from use of various types of cellophane-polythene films were unpredictable, inasmuch as some films were surprisingly well tolerated by the tissues. In 1948, Yeager and Cowley<sup>57</sup> identified dicetyl phosphate, a stripping agent used in manufacture, as the irritating substance, and since that date, it has been possible to select

TABLE I.

Case No.	Color, Sex, and Age	Date Operated	Aneurysm		Surgical Procedure	Result and Remarks
			Nature	Situation		
1. R.M.	C.M. 46	12/22/48	Syphilitic	Transverse arch	Proximal ligation with cellophane reinforced ligature (rubber catheter)	Apparently well for 2 months and then developed fatal hemorrhage
2. R.R.	W.M. 32	4/28/50	Spontaneous	Rt. subclav.	Proximal and distal ligation with total excision	Cured
3. J.M.	C.M. 46	7/12/51	Syphilitic	Innominate and adjacent aorta	Ligation of subclavian and carotid, aneurysmectomy, and aortorrhaphy	Cured
4. F.D.	W.M. 57	10/ 4/51	Syphilitic	Ascending and transverse arch	Aneurysmectomy and aortorrhaphy	Died 14 hours after operation, diffuse cerebral damage, anesthetic complication
5. L.H.	C.M. 41	9/ 6/51	Syphilitic	Terminal thoracic aorta	Aneurysmorrhaphy and cellophane wrapping, subsequent wiring	Died 18 days after operation, secondary hemorrhage
6. W.F.	W.M. 56	9/ 7/51	Syphilitic and arteriosclerotic	Transverse arch	Cellophane wrapping	Improved

tenacious, clot-stimulating, protein coagulum formed on the wire and the thrombus extended throughout the aneurysm. Blakemore<sup>6</sup> has recently presented convincing evidence of the value of this method in the relief of pain, the protection against rupture and the rehabilitation of the patients.

*Stimulation of Periarterial Fibrosis.* In 1939, Page<sup>43</sup> first called attention to the irritating properties of cellophane, which he used to wrap the kidneys of dogs in order to produce experimental hypertension. The following year Pearse<sup>44</sup> employed cellophane as an experimental means of gradual occlusion of large arteries, and three years later Harrison and Chandy<sup>26</sup> applied this method in the treatment of an aneurysm of the subclavian artery. Subsequently, Poppe and De Oliveira<sup>46</sup> employed cellophane and

suitable polythene films for the purpose. Good results following the use of polythene-cellophane in aneurysms of the aorta have been reported by a number of observers.<sup>1, 15, 17, 39, 45</sup> From these experiences as well as our own the use of polythene-cellophane film would appear to have definite value in certain instances where a more direct approach is not feasible.

The recent suggestion of Berman and his associates<sup>4</sup> of the injection of a solution of dicetyl phosphate (0.9 per cent in olive oil) provides distinct advantages over the "wrapping" technic, in that it permits simpler and safer placement of the fibrous tissue-producing substance in contact with all surfaces of the aneurysm.

*Endo-aneurysmorrhaphy.* Matas<sup>35</sup> contribution of endo-aneurysmorrhaphy, in 1888,



constituted the most important landmark in the surgical management of aneurysms. This experience led to his later development<sup>36, 37</sup> of the procedure in its three forms, the obliterative, the restorative, and the reconstructive endo-aneurysmorrhaphy. For over a half a century<sup>21</sup> this principle of intrasac-

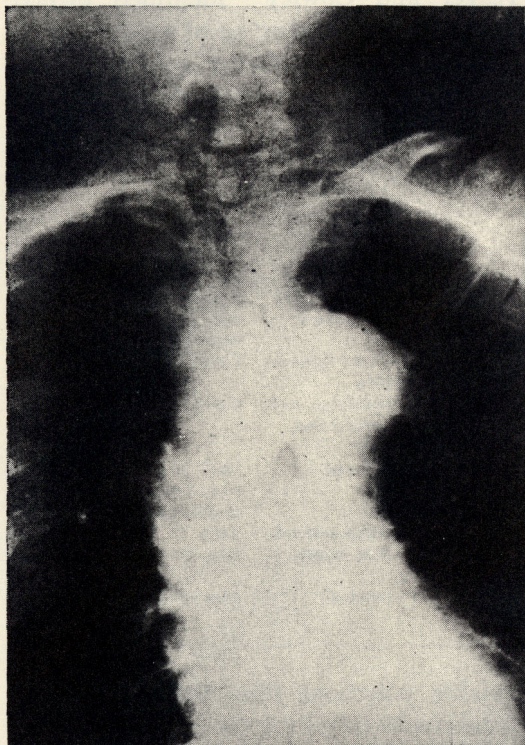


FIG. 1.—Roentgenogram of chest in Case 1 showing widening of superior mediastinal shadow, slight tracheal displacement to the right and dilatation and calcification of the aortic arch.

cular suture has enjoyed wide usefulness in peripheral aneurysms but unfortunately it has not been found readily applicable to intrathoracic aneurysms of the aorta and its major branches. Indeed the case recently reported by Lane and Peirce<sup>31</sup> appears to be the first recorded instance in which endo-aneurysmorrhaphy was used in treating such an aneurysm.

**Excision.** Few cases of extirpation of intrathoracic aneurysms of the aorta or its major branches have been recorded. To our knowledge there has been no case in-

volving the left common carotid artery in its intrathoracic portion treated by this means. There have been four cases of aneurysms of the innominate artery successfully treated by complete or partial extirpation. The first was performed by Kimura,<sup>27</sup> in 1908, in a 46-year-old male with a spontaneous aneurysm involving the innominate artery near its bifurcation. After proximal and distal, or so-called "triple ligation," the sac was partially removed. In the second case, consisting of a saccular aneurysm of the innominate artery in a 64-year-old female, proximal ligation was first performed by Tudor Edwards on June 11, 1935, but owing to recurrence and persistence of symptoms a second operation was performed on May 11, 1936, by E. R. Carling, who excised the aneurysm after ligating the common carotid, subclavian and innominate arteries.<sup>47</sup> In the third case, a saccular aneurysm of traumatic origin in a 25-year-old male, reported by Shumacker,<sup>50</sup> partial proximal ligation was done with fascia lata and cellophane at the first operation and two and one-half months later the carotid and subclavian arteries distal to the aneurysms were divided between ligatures, the innominate artery proximal to the aneurysm was doubly ligated, and the sac widely opened and its contents evacuated. The fourth case was mentioned by Blakemore,<sup>5</sup> in 1948, and while the precise nature of the findings and procedure is not described, it appears to have consisted of excision of a syphilitic aneurysm of the innominate artery at its origin, with repair of the opening in the aorta by running mattress suture. Significantly, in all but the last of these cases, the aneurysm did not involve the origin of the artery.

Successful excision of an aneurysm involving the intrathoracic part of the subclavian artery has been reported in three instances. The first case by Chapman,<sup>10</sup> in 1929, consisted of a traumatic aneurysm of the right subclavian. Owing to severe hemorrhage, consequent to rupture of the thin-



walled sac during the operation, it was necessary to ligate the innominate and carotid arteries as well as the subclavian distal to the sac, which was then excised. The second case, reported by Temple<sup>54</sup> in 1950, in a 40-year-old male, was probably of trau-

tion, the aneurysms typically appear just distal to the constriction and may be related in some manner to the factors which produce the post-stenotic dilation commonly encountered in the distal segment of that vessel. Aneurysms of this type lend them-

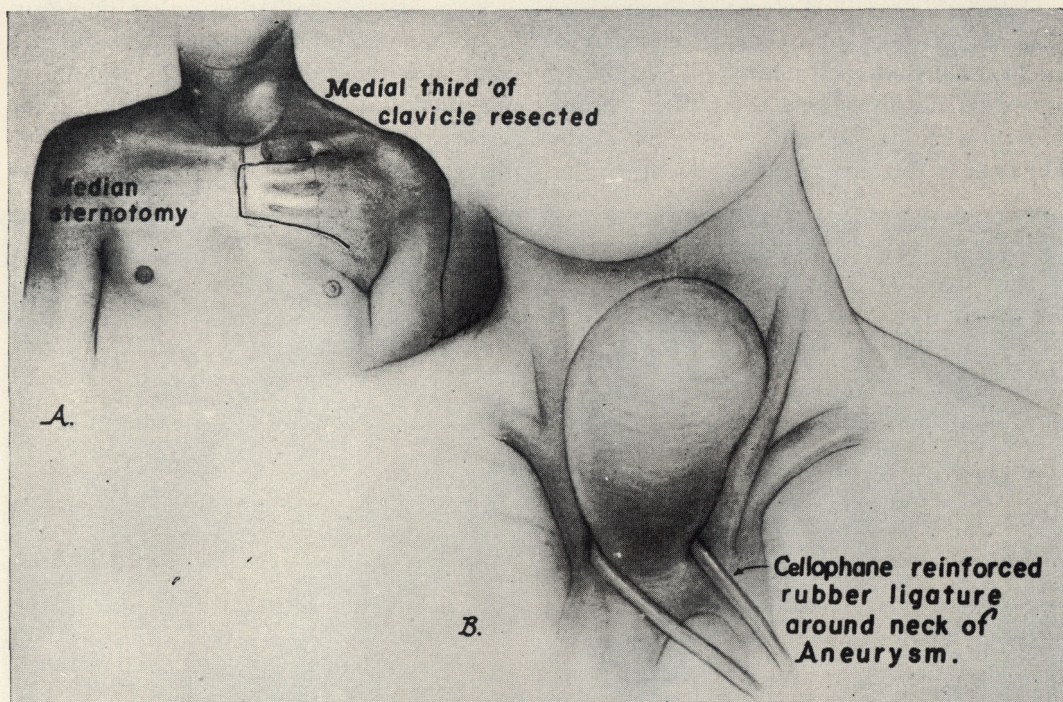


FIG. 2.—Drawing of operative procedure and findings in Case 1, showing approach in A and the sacciform aneurysm in B arising from the anterior superior border of the transverse aortic arch between the innominate and carotid arteries, with placement of cellophane reinforced ligature around its neck.

matic origin involving the left subclavian artery and arising about one inch from the aortic arch. After proximal and distal ligation of the main vessel, the aneurysm was removed. The third case, in a 38-year-old colored female, was recently reported by Daniel<sup>16</sup> and concerned a large syphilitic aneurysm arising from the right subclavian artery just distal to its origin. The aneurysm was excised after proximal and distal ligation of the subclavian artery.

The reports of cases of excision of aortic aneurysms can be conveniently divided into two groups, depending upon whether or not there was an associated coarctation of the aorta. In those associated with coarcta-

tion, the aneurysms typically appear just distal to the constriction and may be related in some manner to the factors which produce the post-stenotic dilation commonly encountered in the distal segment of that vessel. Aneurysms of this type lend themselves more easily to extirpation because of the relatively low intraluminal pressure and the well-developed collateral vessels which supply the lower half of the body if the aorta must for any reason be occluded. Alexander and Byron,<sup>2</sup> in 1944, first successfully removed such a lesion but did not attempt restoration of aortic continuity. Shumacker<sup>52</sup> excised completely a small aneurysm as well as the area of coarctation, and then anastomosed the aortic ends primarily. Using an aortic homograft Swan<sup>53</sup> bridged the defect remaining after a similar excision, and recently Gross<sup>24</sup> reported five such cases.

We have been able to find only two suc-



cessful cases of excision of an aortic aneurysm not associated with coarctation. Tuffier<sup>55</sup> deserves credit for suggesting the technic, which was also designed to preserve the continuity of the aorta, despite his unsuccessful attempts in several cases.

Ochsner<sup>42</sup> described a case in September, 1944, in a 45-year-old male with a suspected mediastinal tumor of neurogenic origin. At operation he discovered a small sacciform aneurysm of the descending thoracic aorta. The base of the aneurysm was clamped, the

#### CASE REPORTS

It is apparent from this résumé that various methods of surgical attack have been employed in the treatment of aneurysms of the thoracic aorta and its major branches. For the most part these efforts have been concerned with palliative rather than curative therapy and the results therefore have been somewhat disappointing. In light of this fact and the grave prognosis of the disease, we have adopted a more aggressive surgical policy in the hope of applying more

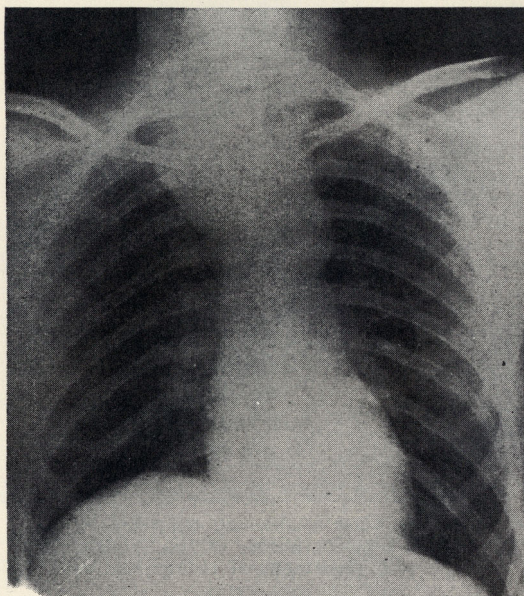


FIG. 3

FIG. 3.—Roentgenogram of chest in Case 2 showing widening of the superior mediastinum to the right produced by the aneurysm, and notching of the ribs consistent with a diagnosis of coarctation of the aorta.

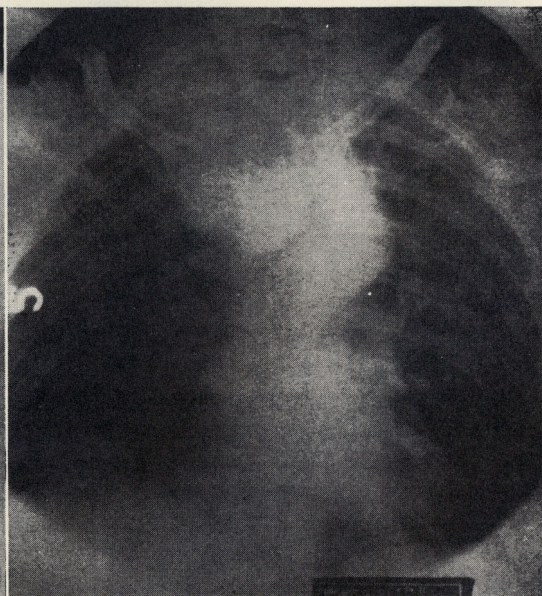


FIG. 4

FIG. 4.—Angiocardiogram in Case 2 showing visualization of the aortic arch, which is slightly displaced to the left by the mediastinal mass containing some dye. The left subclavian and both common carotid arteries are readily visualized but no filling is apparent in the right subclavian.

sac excised and the aorta was sutured. The patient made an uneventful recovery.

The second somewhat similar case, in a 20-year-old woman, was reported several years later by Monod,<sup>38</sup> who excised an aneurysm of the aorta distal to the left subclavian artery and then sutured the defect, which was approximately 4 cm. in length, thus preserving continuity of that vessel.

effective surgical procedures. The various factors influencing the feasibility and the type of surgical therapy are illustrated by the following case reports, which are summarized in Table I.

Case 1.—R. M., a colored male, 46 years old, was admitted November 30, 1948, to Jefferson Davis Hospital. He complained of a painful pulsating mass in the neck of one year's duration. There was a history of inadequately treated primary



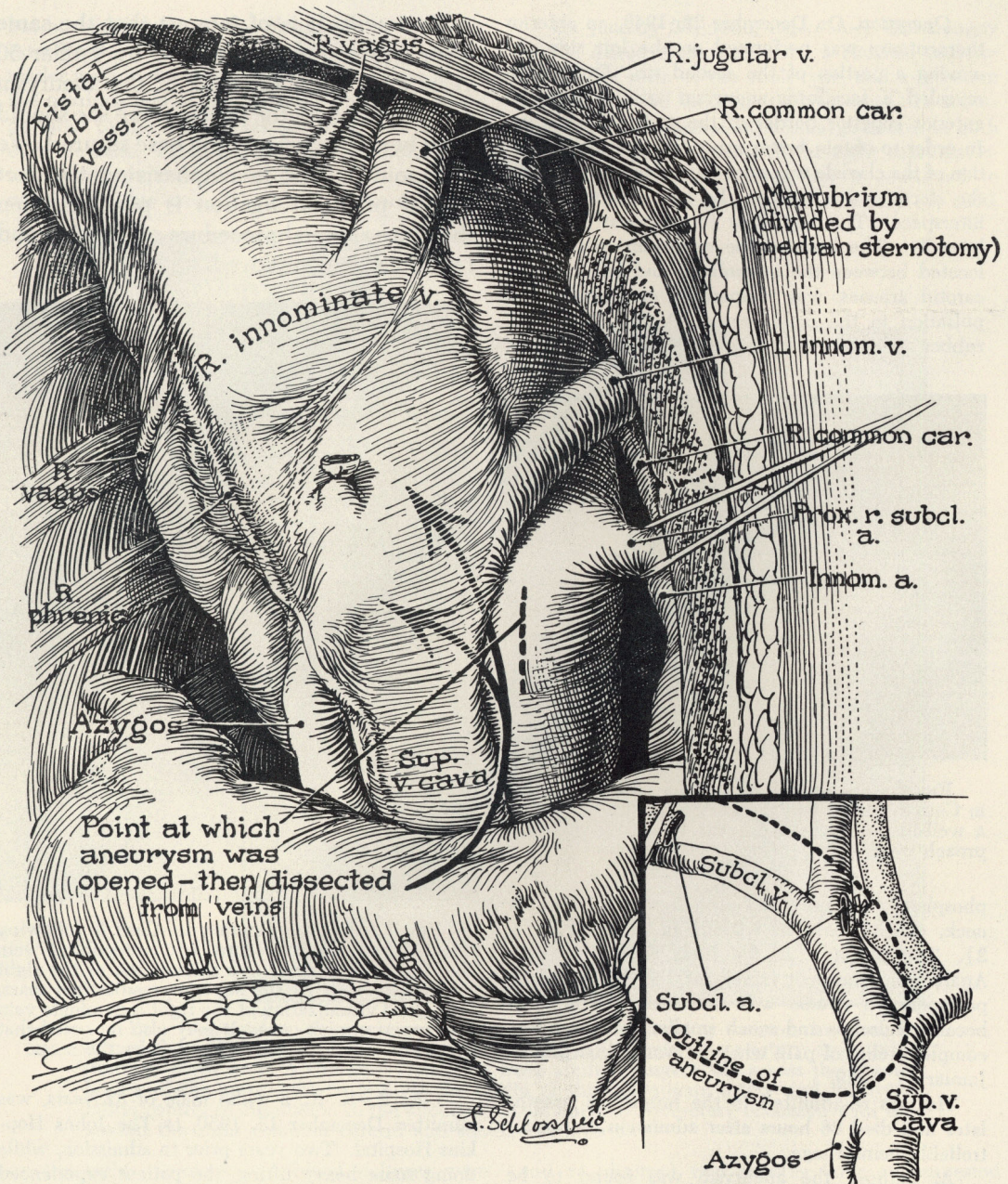


FIG. 5.—Drawing showing operative findings and procedure employed in Case 2.

syphilis 27 years before. The mass presented in the left side of the neck above the sternoclavicular joint and pulsated vigorously. Blood pressure in the right arm was 112/80 and in the left arm 120/78.

Roentgenographic examination revealed a relatively normal cardiac silhouette with a widened superior mediastinal shadow, slight displacement

of the trachea to the right and some dilatation and calcification of the aortic arch (Fig. 1). There were strongly positive serologic Kolmer and Kline tests for syphilis. It was apparent clinically that the mass was increasing rapidly in size, and the pain becoming more marked. A diagnosis of aneurysm of the arch of the aorta, probably of syphilitic origin, was made.



**Operation.** On December 22, 1948, an anterior thoracotomy was performed on the left side, removing a portion of the second rib. Exploration revealed a sacciform aneurysm arising from the anterior superior border of the arch of the aorta. In order to obtain better exposure, the medial portion of the clavicle was removed subperiosteally and the sternum was split to the level of the second interspace. The flap thus formed was retracted laterally. The base of the aneurysm, which was located between the innominate and left common carotid arteries, was temporarily compressed and pulsation in the mass ceased. A No. 24 French rubber catheter was encased in a polythene dicetyl

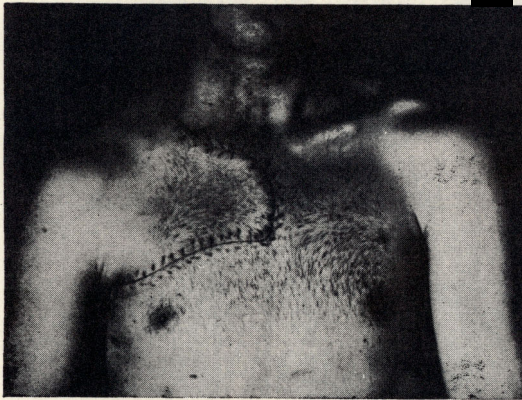


FIG. 6.—Photograph of anterior chest of patient in Case 2 taken two weeks after operation showing a well-healed incision for the thoracocervical approach used.

phosphate film and used as a ligature about the neck, which measured 2.0 cm. in diameter (Fig. 2). The pulsation in the mass was obliterated. Apart from transient edema of the left arm, the postoperative course was uneventful. The mass became pulseless and much smaller and there was complete relief of pain when he was discharged on January 7, 1949.

He was re-admitted to the hospital 2 months later and died 36 hours after admission of uncontrollable hemorrhage.

At autopsy the aneurysm was found to be ruptured at its distal portion with the opening extending directly through the skin in the supra-sternal region. The neck of the aneurysm measured about 1.5 cm. in diameter and was located on the anterior superior border of the arch between the origin of the innominate and the carotid arteries. There was dense fibrous tissue, in some areas almost 1 cm. in thickness, surrounding the neck of the aneurysm and around the polythene-encased catheter ligature.

**Comment.** It is of interest that the same error was committed here as by Tuffier 50 years ago. After the neck of the aneurysm was occluded by the ligature, the sac should have been excised and the base sutured. We now join Tuffier in emphasizing the fact that if proximal ligation is possible, then the more rational procedure of excision and repair can be employed.

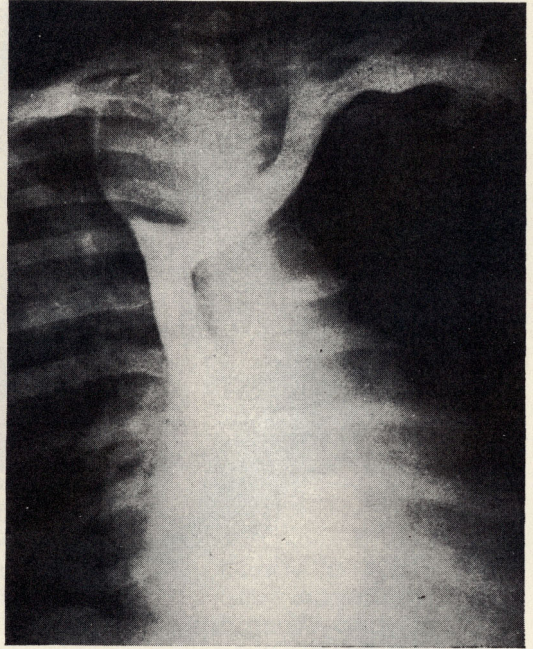


FIG. 7.—Angiocardiogram in Case 3 following injection of Diodrast into left antecubital vein showing displacement and attenuation of the right innominate vein by the superior mediastinal mass, with good visualization of the right innominate vein and superior vena cava. It may also be noted that the trachea is displaced to the left by the mass.

**Case 2.**—R. R., a white male of 32 years, was admitted December 15, 1950, to The Johns Hopkins Hospital. Two years prior to admission, while doing some heavy lifting, the patient experienced sharp pain in the right lower neck. Pain came on suddenly but subsided spontaneously after three weeks, but a non-pulsating supraclavicular mass persisted. Six days prior to this admission, again while doing some heavy lifting, the patient experienced pain in the lower part of the neck which radiated down the right arm, and the mass was larger.

Physical examination on admission revealed a blood pressure of 170/105 in the upper extremities,



but no blood pressure was obtainable in the lower extremities. There was a pulsating and slightly tender mass in the right supraclavicular fossa above the proximal end of the clavicle. The trachea was deviated to the left. A systolic bruit was audible over the mass. There was weakness of motor function in the right arm and distended veins were noted over this area. There was a Horner's sign

On January 30, 1950, exploratory thoracotomy by Dr. Alfred Blalock revealed a classical coarctation of the aorta of the adult type, and a resection with end-to-end anastomosis was done. Postoperatively he had equivalent, normal pressures in both arms and legs. The mass in the right supraclavicular fossa appeared smaller, but it continued to pulsate. He was discharged on February 17, 1950,

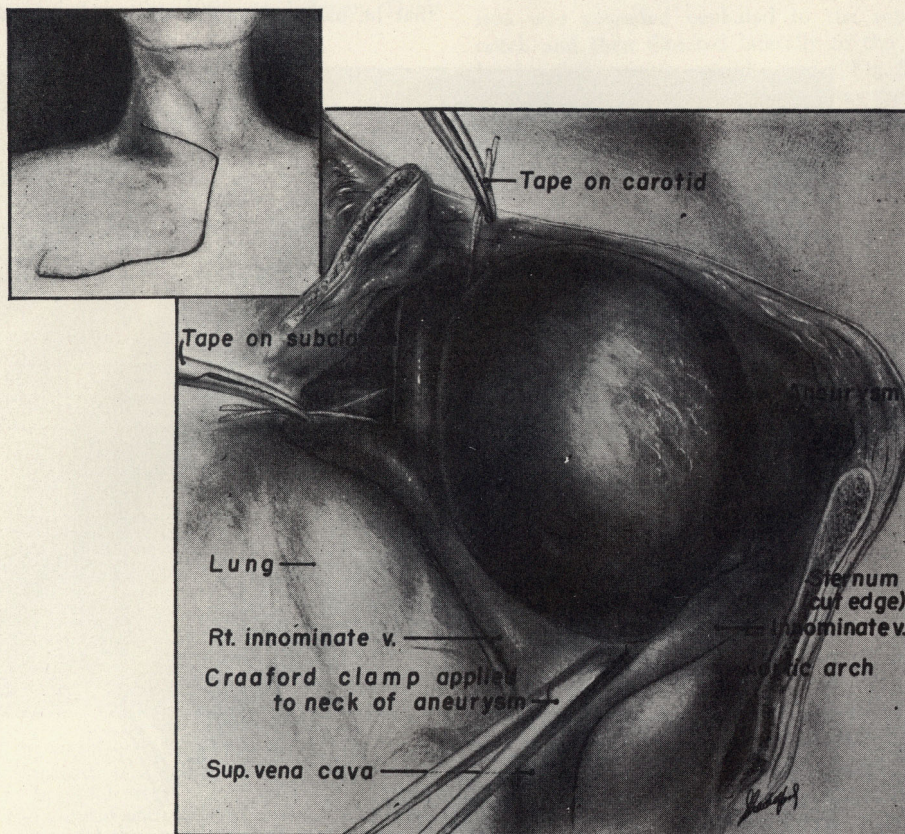


FIG. 8.—Drawing of operative findings in Case 3, showing incision in inset for thoracocervical approach and the aneurysm arising in the innominate artery at its origin from the aortic arch. A Crafoord clamp has been applied tangentially across the superior border of the aortic arch to occlude the origin of the innominate artery and aneurysm. Distal control of circulation in the aneurysm is obtained by temporary occlusion with tape around the right common carotid and subclavian arteries.

on the right. Serology and blood cultures were negative. The venous pressure in the left arm was 78 mm. of saline and in the right, 230 mm. of saline. Roentgenograms of the chest revealed a prominent superior mediastinal shadow and marked notching of the ribs, consistent with a diagnosis of coarctation of the aorta (Fig. 3). Angiocardiography showed slight displacement of the aortic arch to the left by the mediastinal mass, with patency of the left subclavian and both common carotid arteries but no visualization of the right subclavian artery (Fig. 4).

and re-admitted two months later as requested when an aortogram failed to reveal an aneurysm. Since discharge he had developed a right recurrent nerve palsy and a partial phrenic palsy. The pulsatile mass was still present in the right supraclavicular region and there was venous distension over the right upper chest and shoulder. A diagnosis of aneurysm of the subclavian artery was made.

**Operation.** On April 28, 1950, exploratory thoracotomy performed (D.A.C.) through the right second interspace anteriorly, revealed a large



## INTRATHORACIC ANEURYSMS OF THE AORTA

aneurysm approximately 12 x 8 cm. in size of the right subclavian artery. The superior vena cava was obstructed and the right innominate vein was attenuated. The azygos vein was greatly enlarged. Additional exposure was obtained by extending the incision cephalad into the suprasternal notch and performing a median sternotomy. The medial third of the right clavicle was resected subperiosteally.

teal bed and the wound closed in layers (Fig. 6). His convalescence was uneventful. At the time of discharge, the function in the right shoulder was good. Two months later the Horner's syndrome had improved and roentgenograms revealed partial return of motion in the right leaf of the diaphragm. A letter dated August 28, 1951, approximately 16 months after operation, indicated that he had returned to work and was well.

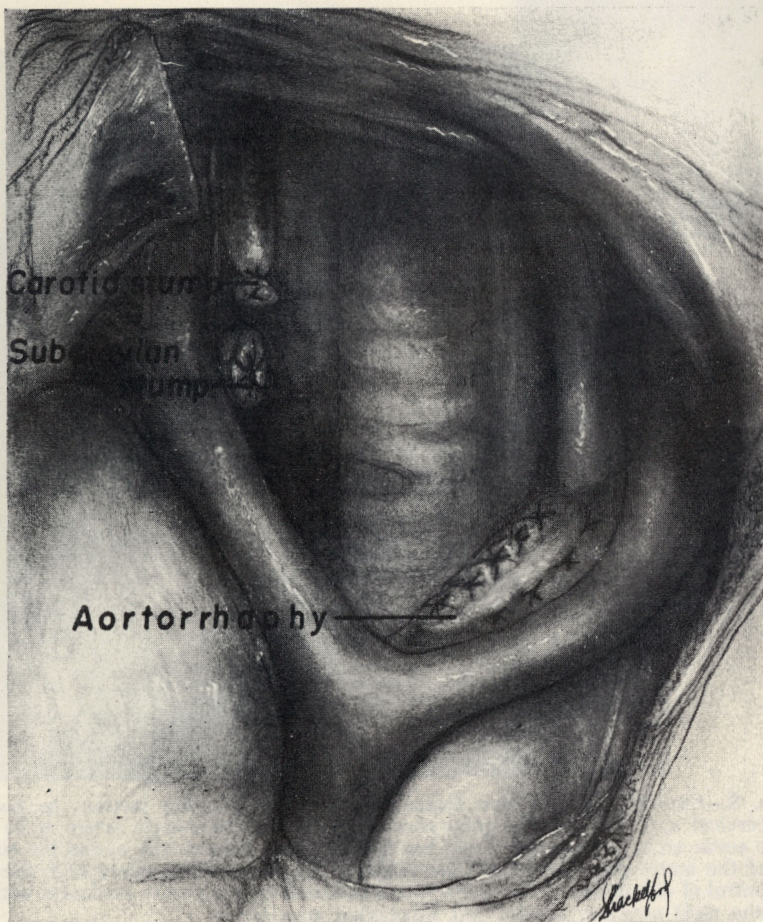


FIG. 9.—Drawing of operative procedure in Case 3 showing completed aortorrhaphy and ligated ends of right common carotid and subclavian arteries after excision of aneurysm.

The aneurysm involved only the subclavian artery (Fig. 5). After the artery was ligated proximally and distally, pulsations ceased. The aneurysm was opened and the sac was excised after evacuating the clot (Fig. 5). The ends of the divided subclavian artery were sutured with interrupted silk. The segment of clavicle which had been removed was replaced as bone chips in the periosteal

*Comment.* The results obtained in this case reflect the advances in vascular surgery. In this patient, surgical correction was obtained for two vascular lesions which less than a decade ago were considered to be inoperable. The case illustrates also the type of aneurysm which, although exten-



sive, lends itself well to extirpation. Collateral circulation after subclavian artery interruption in its first portion is usually adequate to support circulation in the upper extremity.

Case 3.—J. M., a colored male, 46 years old, was admitted June 29, 1951, to Jefferson Davis

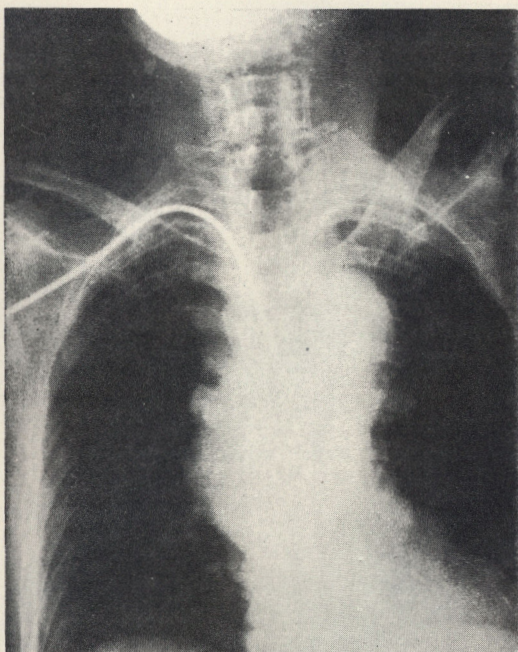


FIG. 10.—Aortogram in Case 4 performed by injecting Diodrast in a catheter introduced through the right brachial artery and permitting visualization of the carotid and subclavian vessels, the arch of the aorta and the origin of the aneurysm from the ascending aorta. The aneurysm is only partly filled with Diodrast, indicating the presence of an intraluminal thrombus.

Hospital. He complained of hoarseness, shortness of breath and a pulsating mass in the right superclavicular region. He had a complete Horner's on the right, right vocal cord palsy and a prominent pulsating superclavicular mass which displaced the trachea to the left. There were numerous dilated veins over the anterior chest on the right. A roentgenogram revealed a mass occupying part of the right lung field displacing the trachea to the left. The aortic arch appeared to be of relatively normal dimensions and there was moderate cardiac enlargement. Angiocardiogram revealed good filling of the left innominate vein and superior vena cava but displacement and attenuation of the right

innominate vein (Fig. 7). The Kahn test was strongly positive and a diagnosis of syphilitic aneurysm of the innominate artery was made.

*Operation.* On July 12, 1951, a right anterior thoracotomy, performed through the second interspace, revealed a large aneurysm eroding the sternum and partially occluding the right innominate vein. In order to obtain better exposure, the incision was extended cephalad to the suprasternal notch and then directed laterally to the posterior border of the sternomastoid muscle (Fig. 8). With one hand beneath the sternum to direct the Lebsche chisel, the sternum was divided longitudinally but the clavicle was not resected. A large sacciform aneurysm, about 10 x 13 cm., was then exposed and found to involve the innominate artery at its origin, with the neck of the aneurysm forming a part of the wall of the arch of the aorta, where it measures 3.5 cm. in diameter (Fig. 8). The aneurysm displaced the trachea to the left. The origin of the innominate artery was dissected free of mediastinal structures and this portion of the arch was occluded with Crafoord clamp (Fig. 8). The pulsation in the aneurysm ceased. The subclavian artery and the right common carotid, which was already partially thrombosed, were ligated. The aneurysm was then entered through an incision on its lateral surface, following which the contained thrombus was evacuated and the sac excised. With the aneurysm removed, the opening into the arch of the aorta was closed with interrupted mattress and figure of eight sutures of black silk (Fig. 9). His postoperative course was satisfactory and he was discharged 17 days later.

He was re-admitted to the hospital on November 15, 1951, complaining of a recurring, severe abdominal pain and a pulsating mass just below the umbilicus. At this time the thoracotomy incision was well healed and function in the right shoulder was normal. On the basis of these findings and an aortogram, a diagnosis of aneurysm of the abdominal aorta was made and was confirmed at laparotomy on November 29, 1951. A fusiform aneurysm the size of a golf ball was demonstrated in the terminal abdominal aorta and this was wrapped with polythene dicetyl phosphate film.

*Comment.* This procedure of aortorraphy after excision of an aneurysm of the innominate artery involving the arch of the aorta has apparently rarely been done. In fact, the only other case we have been able to find in the literature that seems to resemble it is the one mentioned by Blakemore.<sup>5</sup> Tuffier, in 1902, recognized that lateral



suture of the aorta would be possible in certain forms of intrathoracic aortic aneurysms following excision, and Rundle, in 1937, after determining the practicability of such a procedure on the cadaver, advocated its use providing the aortic wall was in a healthy condition. From our experience we

in every intended ligation involving carotid circulation, a test of temporary digital compression of that vessel is mandatory.

**Case 4.**—F. D., a white male of 57 years, was admitted September 27, 1951, to Jefferson Davis Hospital complaining of pain in the right side of the neck and shoulder and a steadily growing mass

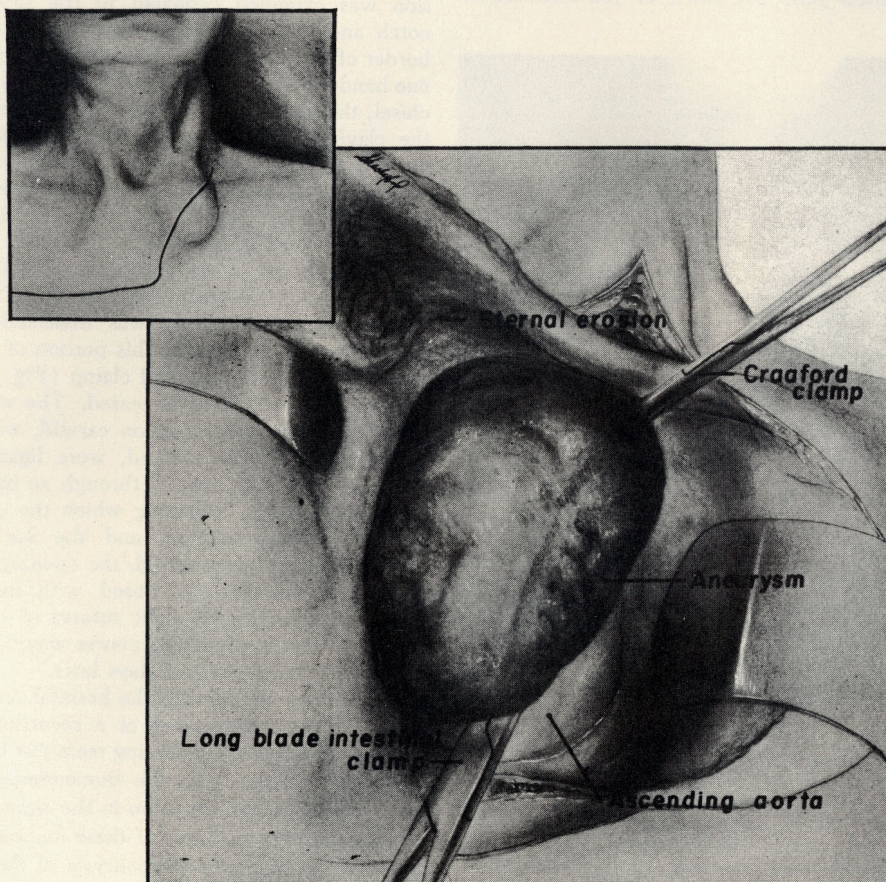


FIG. 11.—Drawing of operative findings in Case 4 showing incision and exposure used in inset and large sacciform aneurysm arising from the anterior part of the ascending aorta and extending through the eroded sternum. Two clamps have been applied tangentially to the ascending aorta across the neck of the aneurysm.

are inclined to believe that the procedure is practicable particularly in syphilitic lesions, owing to the leathery consistency of the aortic wall which lends itself well to suture. Collateral circulation after innominate division here was adequate. Carotid pulsation was known to be diminished and the carotid compression test of Matas, prior to surgical attack, was negative. Obviously,

in the suprasternal region. There was a history of inadequately treated primary syphilis. A pulsatile mass was present over the manubrium, extending upward into the suprasternal region slightly to the left of the midline and the overlying skin was darkly discolored. Neurologic examination revealed hyperactive tendon reflexes and unsustained ankle clonus. He walked with a scissors gait.

Blood and spinal fluid tests for syphilis were inconclusive. The chest film revealed only slight cardiac enlargement to the left. An enlarged aortic



shadow ascending to the level of the sternoclavicular junction was suggestive of an aortic aneurysm and special films of the manubrium revealed an erosion measuring 3 cm. in diameter, with some regeneration of bone at the periphery.

The aortogram permitted visualization of the carotid and subclavian arteries, the arch of the aorta and the origin of the aneurysm from the ascending aorta (Fig. 10).

crossed anteriorly to the aneurysm was divided and the base of the aneurysm was defined. Two clamps were applied tangentially to the ascending aorta across the neck of the aneurysm, which measured approximately 6 cm. in diameter, following which the aneurysm was amputated (Fig. 11). The aneurysm did not involve the great vessels arising from the arch of the aorta. The laminated clot extended through the sternum and into the supra-

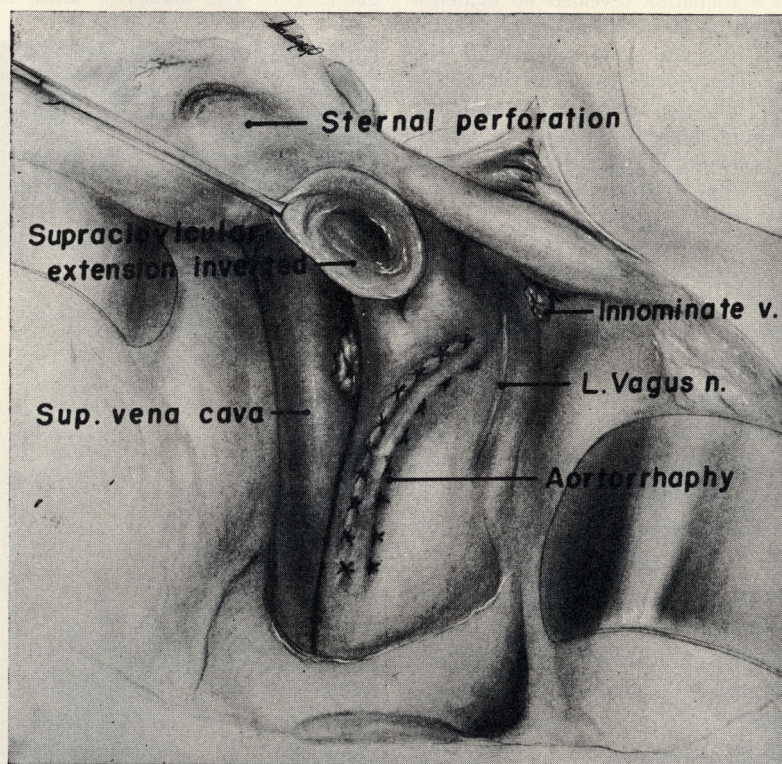


FIG. 12.—Drawing showing operative procedure performed in Case 4, the latter showing lateral aortorrhaphy following excision of aneurysm. The supraclavicular extension of the aneurysm through the eroded manubrium has been inverted and the thrombus evacuated.

**Operation.** On October 4, 1951, a right anterior thoracotomy through the third interspace revealed a large aneurysm in the anterior superior mediastinum arising from the ascending arch of the aorta and penetrating the manubrium (Fig. 11). After preliminary dissection, it was apparent that additional exposure was necessary, and this was obtained by dividing the sternum transversely at the level of the third interspace and later dividing the left third, second, and first costal cartilages. The pericardial sac over the base of the heart was opened widely in order to identify the course of the aorta. The obliterated left innominate vein which

clavicular subcutaneous tissues on the left. The aortic defect was closed with a layer of interrupted mattress sutures and reinforcing figure-of-eight sutures, using 4-0 silk (Fig. 12). During the extensive dissection the left pleural space was entered, but this fact was recognized promptly and the anesthetist was informed. The sternum was drilled and the edges were approximated with heavy braided silk sutures, following which the incision was closed in layers and chest catheters for drainage placed in both pleural cavities. An elective tracheotomy was performed as a precautionary measure. He withstood the operation very well and received 3000 cc.



## INTRATHORACIC ANEURYSMS OF THE AORTA

of transfused whole blood. At the completion of the five and one half hour procedure his blood pressure was 110/80 and his pulse was 88.

For the first few hours postoperatively nothing abnormal was noticed, but later it became apparent that there was diffuse cerebral damage. Cheyne-Stokes periodic respiration began during the night and 14 hours after operation he became cyanotic and respirations ceased.

Postmortem examination revealed no evidence of hemorrhage and an intact aortic repair. Examination of the brain revealed no evidence of vascular occlusion. The precise cause of death was not ascertained, but the most likely possibility seemed to be diffuse cerebral damage of an anoxic type, probably occurring during surgery, as a consequence of the bilateral open thorax and inadequate ventilation.

*Comment.* This case, like the previous one, demonstrates further the practicability and usefulness of aortorrhaphy after excision of a saccular aneurysm. Moderate atherosclerosis was present, but the consistency of the aortic wall was similar to that in Case 3, providing additional evidence that the pathologic process in syphilitic lesions permits suture. Two large clamps were required to occlude the neck of the lesion, but after aortic repair the clamps were removed without hemorrhage. The surgical approach employed was improvised and necessarily extensive, involving a bilateral pleural entry. Under these circumstances, constant attention by the anesthetist is imperative in order to provide adequate pulmonary ventilation. Prophylactic tracheotomy in a case of this type facilitates removal of bronchial secretions by catheter and minimizes respiratory effort.

**Case 5.**—L. H., a colored male of 41 years, was admitted August 9, 1951, to Jefferson Davis Hospital. He complained of a continuous pain in the left lower chest posteriorly of 2 months duration. In 1942 he was treated with penicillin, presumably for syphilis. He was emaciated and appeared chronically ill. There was a pulsating mass at the level of the angles of the left ninth and tenth ribs. The Kline test for syphilis was positive. Chest roentgenograms revealed a mass in the left cardiophrenic angle lying posteriorly, with erosion of the ninth, tenth, and eleventh ribs. An aortogram

demonstrated a sacciform aneurysm of the lower thoracic aorta, extending from T9 to L1 (Fig. 13). He received 12,000,000 units of penicillin as anti-syphilitic treatment.

*Operation.* At thoracotomy on September 6, 1951, through the bed of the excised eighth rib, there was found a large aneurysm about 20 cm. in diameter, which lay in the paravertebral sulcus originating above and extending well below the diaphragm. The aneurysm arose from the pos-

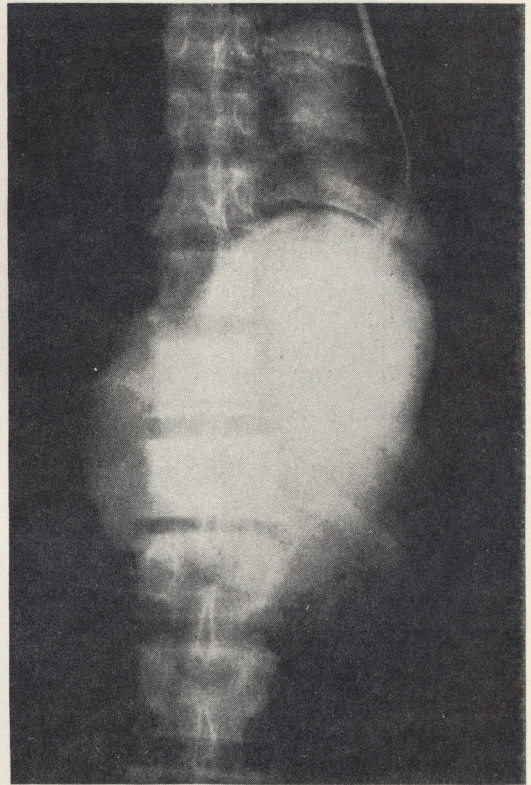


FIG. 13.—Aortogram in Case 5 showing a large sacciform aneurysm of the descending thoracic aorta extending from the level of T9 to L1.

terior surface of the terminal thoracic aorta, and the ostium was about 10 cm. in length. In order to obtain better exposure, the incision was carried across the costal margin to convert the thoracotomy into a thoraco-abdominal approach (Fig. 14). Temporary cotton tapes for traction were passed about the aorta proximal and distal to the mass. The proximal aorta was about twice the caliber of the distal. It was hoped that an excision of the mass could be carried out, but the difficulty was in finding an instrument which would occlude the base of the aneurysm. Efforts to improvise a suitable instrument were time consuming and fruitless.



It was finally decided that temporary proximal occlusion of the aorta was indicated. While the proximal aorta was clamped, a layer of interrupted mattress sutures was placed in the neck of the aneurysm (Fig. 14). The temporary occlusion lasted 22 minutes. To our disappointment there was a strong pulsation still present in the aneurysm, indicating a rich collateral circulation through the intercostal vessels. There had been excessive blood loss during the prolonged procedure, and further attempts at excision appeared unwise. The aneurysm was then covered with a layer of polythene dicetyl phosphate film and the incision was closed.

He received several blood transfusions in the next few days and his blood pressure was maintained above shock levels. There was a bilateral hemothorax which was relieved by thoracentesis. His pain was less severe than before operation and pulsation in the mass was less marked. Postoperatively a total of 100 feet of No. 32 stainless steel wire was inserted under local anesthesia into the aneurysm and pulsation and pain were temporarily relieved (Fig. 15). However, he continued steadily to go downhill and expired on September 24, 1951. Postmortem examination revealed secondary hemorrhage, and dissection of blood along the aorta up to the left supraclavicular fossa.

*Comment.* The approach to aneurysms of the descending aorta is preferably obtained by a standard posterolateral incision. Considerable delay would have been avoided had we anticipated before operation the type of aneurysm clamp we would need. This case is somewhat similar to that recently reported by Lam and Aram<sup>30</sup> in which an aneurysm of the descending thoracic aorta was bypassed by an aortic homograft, but the patient died three months later of infection developing in the aneurysmal sac and secondary hemorrhage. In our case the aneurysm extended as far as the celiac axis, precluding the use of an aortic homograft. Although the blood flow into the aneurysm from the aorta was arrested by lateral mattress sutures (comparable to proximal ligation), this procedure proved ineffectual owing to the continued circulation of blood into the sac through collateral vessels, namely the intercostals.

Probably the procedure of choice in this case would have been temporary occlusion

of the aorta, incision of the aneurysm and evacuation of the clot, followed by suture closure of the collateral ostia, partial excision of the sac, and then lateral aortorraphy.

Finally, and of particular interest, is the fact that renal studies performed after operation by Dr. B. W. Haynes revealed minimal depression of function despite temporary aortic occlusion for 22 minutes.

*Case 6.*—W. F., a white male of 56 years was admitted June 15, 1951, to the Veterans Administration Hospital, Houston, Texas. The patient complained of anginal type pains radiating down the inner aspect of the left arm for about a year. Four years prior to admission he was told that he had syphilis and was treated by gluteal injections and penicillin.

Physical findings were not remarkable. The Mazzini and Kahn tests for syphilis were positive. Roentgenograms of the chest showed a superior mediastinal shadow extending into the left lung field with a rounded, partially calcified border (Fig. 16). The aortogram was interpreted as showing an aneurysm of the arch which contained a thrombus, practically filling the entire sac.

*Operation.* Exploratory thoracotomy on September 7, 1951, through the third anterior interspace on the left revealed a sacciform aneurysm about 10 cm. in diameter arising from the arch of the aorta. In order to obtain better access to the arch the incision was extended over the sternum and up the middle into the suprasternal notch, the sternum being divided by the Lebsche chisel. The apex of the left lung was dissected away from the aneurysm where it was densely adherent. An attempt to remove the visceral pleura from the aneurysm exposed some of the enclosed laminated clot. Because the wall of the aneurysm was thin and calcified and crackled like an eggshell during the preliminary attempt at occluding its base digitally, it was thought that the application of an occluding clamp might well cause a fracture and rupture of the aorta with fatal hemorrhage. For this reason the aneurysm was simply wrapped with irritant polythene film.

The postoperative course was satisfactory and he was discharged on October 25, 1951, at which time he was comfortable and experiencing none of his previous pain.

*Comment.* This patient illustrates the type of case where cure by surgical excision is precluded by the pathologic character of



# INTRATHORACIC ANEURYSMS OF THE AORTA

the adjacent aortic wall. The aneurysm itself was friable, thin walled, and atherosclerotic, making manipulation hazardous. Intracascular thrombosis was complete and wiring as an alternative procedure would

tively short survival period of most patients with this disease, and particularly those with aneurysms of the thoracic aorta, is not sufficiently appreciated. The latter fact is strikingly shown by Kampmeier's<sup>28</sup> excel-

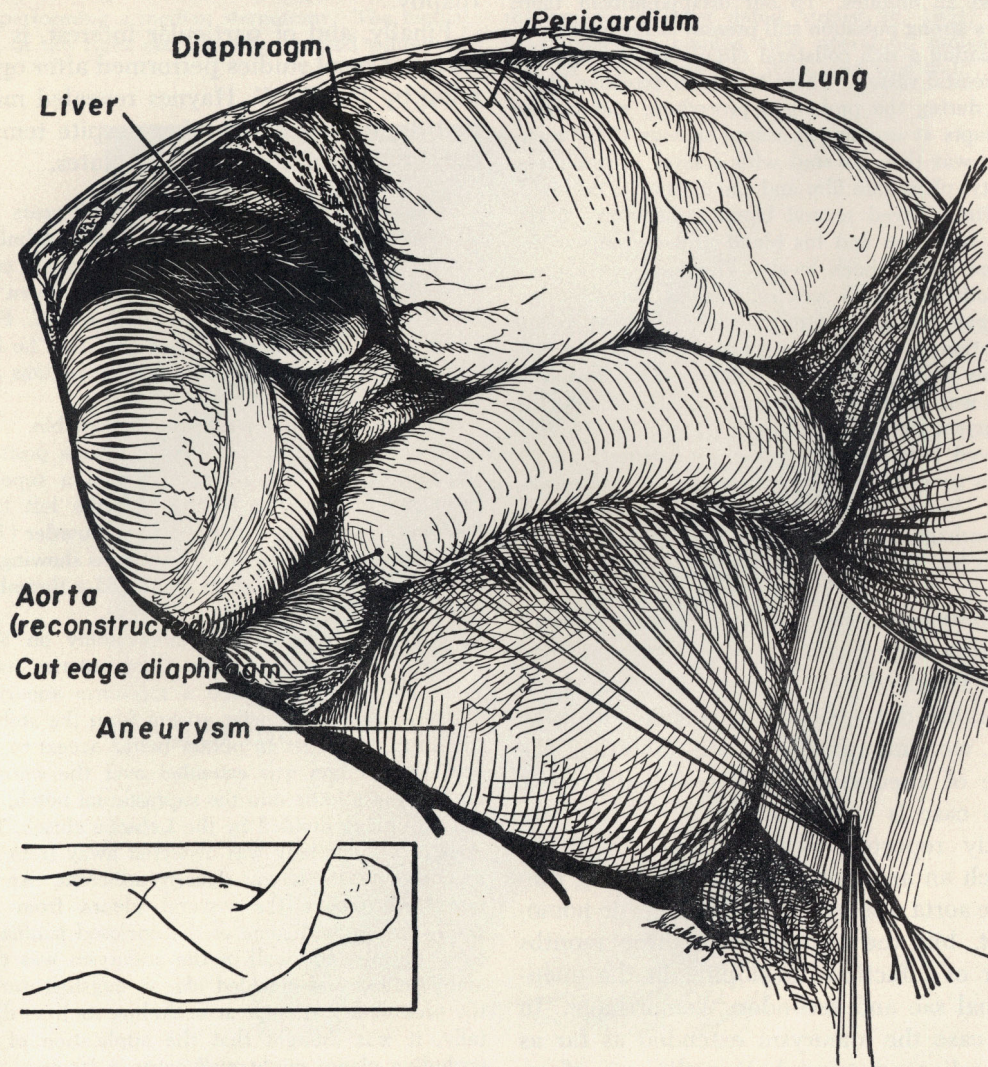


FIG. 14.—Drawing of operative procedure in Case 5 showing thoraco-abdominal approach, the large sacciform aneurysm arising from the posterior wall of the aorta, and the application of mattress sutures across the neck of the aneurysm after temporary occlusion of the proximal aorta.

have been useless. Stimulation of periarterial fibrosis by polythene-dicetyl phosphate provided the most logical solution.

## DISCUSSION

The grave prognosis of aneurysms of the aorta is generally well known, but the rela-

lent analysis based upon a combined series of 1113 patients with saccular aneurysms of the aorta. With comparatively few exceptions, Kampmeier concluded that the duration of life after the onset of symptoms in aneurysms of the thoracic aorta is to be



measured in months, the average figure for the patients in his series being six to eight months. He recognized that there are cases of exceptionally long duration and reported two such cases, one of 14 years and the other 15 years, but emphasized their rarity. From this study as well as other extensive reviews<sup>9, 12, 13, 25</sup> it is readily apparent that aneurysm of the thoracic aorta is a fatal disorder, comparable in this respect to cancer. Under the circumstances, an aggressive attitude, with emphasis on removal of the diseased tissue and reconstruction of the vessel where possible, is highly desirable and justifiable. Every effort should be made to arrive at the diagnosis as soon as possible, but despite the most thorough studies, the precise diagnosis will often remain in doubt unless exploratory thoracotomy is done. Providing the patient's condition permits operation without undue risk, the gravity of the disease fully justifies exploratory thoracotomy not only to establish the diagnosis but also to determine the applicability of the appropriate surgical treatment.

In view of the fact that patients of this type frequently have associated cardiac disturbances, it is highly desirable to evaluate cardiac reserve and provide the indicated supportive therapy.

The surgical approach should be individualized, depending upon the findings in each case. In general, the approach depends upon the location of the aneurysm. The anterior approach is usually preferable when the lesion involves the ascending aorta or arch, whereas a standard posterolateral thoracotomy serves better for lesions of the descending aorta. Early writers including Bardenhauer,<sup>3</sup> Kocher<sup>29</sup> and Sauerbruch<sup>49</sup> described the operative exposure of the anterior mediastinum which was employed in the unusual case of mediastinal exploration. Milton<sup>40</sup> explored the anterior mediastinum, in 1897, after splitting the sternum longitudinally, and modifications of this technic were subsequently developed by Lillienthal,<sup>32</sup> Dunhill,<sup>18</sup> and Churchill.<sup>11</sup> The var-

ious methods of operative exposure of the blood vessels in the superior mediastinum have been recently considered in the papers of Elkin,<sup>19, 20</sup> Shumacker,<sup>51</sup> and Wilson and Carr.<sup>56</sup>

For several reasons in our cases, this technic of exposure has been modified. The larger saccular aneurysms of the type reported here require wide exposure in order to obtain accurate definition of the lesion and to secure control of the vessels. An anterior thoracotomy through the second or occasionally third intercostal space fulfills these requirements best. A preliminary dissection of the aneurysm at its aortic end will usually provide information concerning the diameter of the neck, the nature of the pathologic process and extent of atherosclerosis and calcification, the suitability of the neck for compression and suturing, and finally, the feasibility of surgical excision. If the aneurysm has eroded bone or encroached upon vital structures, proximal temporary or permanent control may be obtained before proceeding further.

In most instances more extensive exposure will be necessary, and this may be achieved quickly and safely with one hand inside the chest to direct the chisel or knife away from the aneurysm. We have found that a Lebsche chisel facilitates extension of the incision into the sternum from the explored interspace after dividing the internal mammary vessels. Depending upon the findings at thoracotomy, this exposure may be obtained either by median sternotomy extending cephalad to the suprasternal notch or by dividing the sternum transversely at the same level and extending it in whichever direction the situation demands. If this dissection involves a bilateral thoracotomy, the necessity for constant alertness on the part of the anesthetist cannot be overemphasized. Resection of the clavicle has not been necessary for the exposure of intrathoracic aneurysms and adds little to the adequacy of the approach.<sup>11, 18</sup>



The most effective surgical procedure which can be used in each case depends upon a number of factors, including particularly the nature, type, and location of the aneurysm. Under certain conditions, such as fusiform aneurysms of the aorta and sacciform aneurysms associated with extensive arteriosclerosis and atheromatous changes, it will be necessary to employ the more conservative procedures directed toward the production of periarterial fibrosis or in-

saccular thrombosis, particularly in sacciform aneurysm in which there is evidence of little or no clot formation. Obviously, only some form of conservative management can be used in patients whose cardiac status and general condition preclude extensive operative intervention. It may be possible, however, in such cases where the aneurysm involves the major vessels of the aorta, to use distal ligation along with "wiring."



FIG. 15

FIG. 15.—Lateral roentgenogram of chest in Case 5 showing coiled wire introduced into the aneurysm.

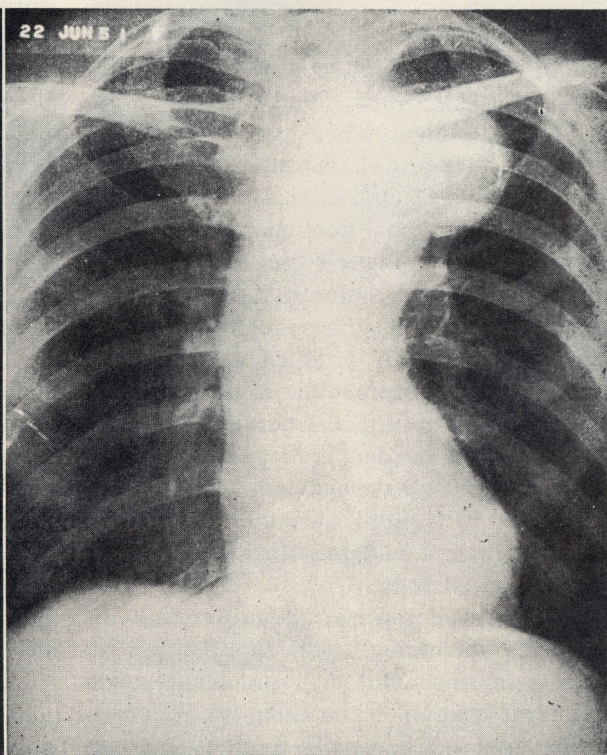


FIG. 16

FIG. 16.—Roentgenogram of the chest in Case 6, showing a well-defined superior mediastinal shadow extending into the left lung field, with a rounded, partially calcified border.

trasaccular thrombosis or both. This is illustrated by our Case 6, in which the arteriosclerotic changes limited the procedure to the "wrapping" technic. The injection of a solution containing dicetyl phosphate around the aneurysm may prove to be a simpler, safer, and more effective method under these circumstances. This may be combined with "wiring" to promote intra-

On the basis of our experience, illustrated by Case 1, as well as the experience of others, proximal ligation alone should rarely, if ever, be used. As emphasized by Tuffier, if proximal ligation is possible, then the more rational procedure of excision and repair can be employed.

The procedure of choice is extirpation of the aneurysm, preferably with restoration



of normal blood flow. The fact that aneurysmectomy for lesions in this area has been done so rarely reflects the infrequency of the set of circumstances which permit its applicability as well as the reluctance to accept the risk involved in such an operation. It is our belief, however, that the procedure may be done more often than has been previously realized and that the risk in competent hands at present is not unreasonable. The procedure is indicated in saciform aneurysms in which the neck is relatively small and the wall of the parent vessel is suitable for suture. This will be most frequently encountered in syphilitic lesions in which there is a tendency to produce a firm but relatively supple, leathery arterial wall.<sup>5, 55</sup> Even in extensive aneurysms of the aorta with a broad base this procedure is possible providing the changes in the aortic wall permit suture, as is well illustrated by our Case 4. In certain circumstances where maintenance of blood flow is vital, such as in the descending aorta or in the carotids when collateral circulation is inadequate, arterial or venous grafts may be used to bridge the defect following extirpation of the aneurysm and parent vessel. Aneurysmorrhaphy may also provide a means of restoration of continuity of the parent vessel, being particularly useful when complete excision of the sac is inadvisable. This probably would have been the procedure of choice in our Case 5.

Extirpation of the aneurysm along with its parent vessel is the procedure of choice in aneurysms involving the major vessels of the thoracic aorta. So long as the collateral circulation in the part supplied by the parent vessel is adequate, the involved artery is preferably sacrificed, as illustrated by our Case 2. Even when the aneurysm involves the origin of the vessels at the aorta, this procedure may be performed providing the aortic wall will hold sutures, as is illustrated by our Case 3.

Various effective methods of lateral arterial suture have been described. The method employed by us seemed particu-

larly satisfactory for the repair of large aortic defects. This consisted in the placement of interrupted mattress sutures of fine silk proximal or distal to the occluding clamp and interrupted figure-of-eight sutures over the ends of the vessel.

#### SUMMARY

1. The various methods of surgical treatment of aneurysms of the intrathoracic aorta and great vessels are briefly reviewed and evaluated. These methods are classified into three major groups: (1) Those designed to induce thrombosis and fibrotic organization of the process by ligation, introduction of foreign material or periarterial fibroblastic reaction, (2) endo-aneurysmorrhaphy, and (3) extirpation of the lesion with or without restoration of blood flow through the parent vessel.

2. Aneurysm of the thoracic aorta is a fatal disorder, comparable in this respect to cancer, emphasizing the need for an aggressive attitude with emphasis on removal of the diseased tissue and reconstruction of the vessel where possible. Providing the patient's condition permits operation without unreasonable risk, the gravity of the disease fully justifies exploratory thoracotomy, not only to establish the diagnosis, but also to determine the applicability of appropriate surgical treatment.

3. Six cases are reported to illustrate the selection of the most effective surgical method, depending upon the nature, type and location of the aneurysm.

4. The exposure advocated consists of an anterior thoracotomy through the second or third intercostal space to determine the nature and extent of the process and the feasibility of surgical excision with subsequent extension of this incision cephalad to the suprasternal notch and median sternotomy, if added exposure is necessary, or by dividing the sternum transversely at the same level and extending it in whichever direction the situation demands. Resection of the clavicle has not been found necessary.

5. The more conservative procedures directed toward the production of periarterial



fibrosis or intrasaccular thrombosis, or both, are indicated under certain conditions, such as fusiform aneurysm of the aorta and sacciform aneurysms associated with extensive arterial sclerosis and atheromatous changes.

6. Proximal ligation alone should rarely, if ever, be used.

7. The procedure of choice is extirpation of the aneurysm, preferably with restoration of normal blood flow. The frequent performance of exploratory thoracotomy in these lesions will permit the application of this procedure more often than has been generally realized. It is indicated in sacciform aneurysms in which the neck is relatively small and the wall of the parent vessel is suitable for suture, as is most frequently encountered in syphilitic lesions.

8. Extirpation of the aneurysm along with its parent vessel is the procedure of choice in aneurysms involving the major vessels of the thoracic aorta. Even when the aneurysm involves the origin of the vessel at the aorta, this procedure may be performed, providing the aortic wall will hold sutures.

9. The technic of lateral arterial suture for repair of large aortic defects is described and illustrated, consisting essentially in the placement of interrupted mattress sutures of fine silk, proximal or distal to the occluding clamp, and interrupted figure-of-eight sutures over the ends of the vessel.

#### BIBLIOGRAPHY

- 1 Abbott, Osler A.: Clinical Experiences with the Application of Polythene Cellophane Upon Aneurysms of the Thoracic Vessels. *J. Thoracic Surg.*, **18**: 435, 1949.
- 2 Alexander, J., and F. X. Byron: Aortectomy for Thoracic Aneurysm. *J. A. M. A.*, **126**: 1139, 1944.
- 3 Bardenhauer: Die Resection des Manubrium Sterni. *Deutsche. Med. Wschnschr.*, **11**: 688, 1885.
- 4 Berman, J. K., F. J. Boyd, Jr., and W. K. Saint: The Treatment of Thoracic and Abdominal Aneurysms of Syphilitic and Arteriosclerotic Origin (Preliminary Report). *J. Indiana M. A.*, **42**: 851, 1949.
- 5 Blakemore, Arthur: The Surgical Aspects of Aneurysm of the Aorta. *Tr. South. S. A.*, **59**: 27, 1947.
- 6 Blakemore, Arthur: Progressive Constrictive Occlusion of the Abdominal Aorta with Wiring and Electrothermic Coagulation. A One-stage Operation for Arteriosclerotic Aneurysms of the Abdominal Aorta. *Ann. Surg.*, **133**: 447, 1951.
- 7 Blakemore, A., and B. G. King: Electrothermic Coagulation of Aortic Aneurysms. *J. A. M. A.*, **111**: 1821, 1938.
- 8 Borrie, John, and G. Selwyn Griffin: Twenty-seven Cases of Syphilitic Aneurysms of the Thoracic Aorta and its Branches. *Thorax*, **5**: 293, 1950.
- 9 Boyd, Linn J.: A Study of Four Thousand Reported Cases of Aneurysms of the Thoracic Aorta. *Am. J. M. Sc.*, **168**: 654, 1924.
- 10 Chapman, C. L. G.: Ligation of Innominate and Common Carotid Arteries for Subclavian Aneurysm. *Brit. M. J.*, **2**: 49, 1929.
- 11 Churchill, Edward D.: Discussion of Paper by Taylor and Wallace. *Ann. Surg.*, **132**: 842, 1950.
- 12 Colt, G. H.: The Clinical Duration of Saccular Aortic Aneurysm in British-born Subjects. *Quart. J. Med.*, **20**: 331, 1927.
- 13 Colt, G. H.: Aneurysm of the Aorta Treated by Wiring. 12 Congress de la Soc. Internat. de Chir., London, September 14-20, pp. 436-439, 1947.
- 14 Corradi: Quoted by Matas.
- 15 Cowley, R. Adams, Herbert E. Sloan and Neil H. Sullenberger: Successful Repair of an Aortic Aneurysm with Sternal Perforation. *J. Thoracic Surg.*, **21**: 159, 1951.
- 16 Daniel, Rollin A., Jr.: Syphilitic Aneurysm of the Subclavian Artery. *Ann. Surg.*, **134**: 251, 1951.
- 17 De Takats, Geza, and R. De Oliveira: The Surgical Treatment of Aneurysm of the Abdominal Aorta. *Surgery*, **21**: 4, 1947.
- 18 Dunhill, T. P.: Removal of Intrathoracic Tumors by the Transsternal Route. *Brit. J. Surg.*, **10**: 4, 1922.
- 19 Elkin, Daniel C.: Arteriovenous Aneurysm. The Approach to the Innominate Vessels. *J. A. M. A.*, **129**: 26, 1946.
- 20 ———: Exposure of Blood Vessels. *J. A. M. A.*, **132**: 421, 1946.
- 21 ———: Traumatic Aneurysm (The Matas Operation—57 Years After). *Surg., Gynec. & Obst.*, **82**: 1, 1946.
- 22 Gordon-Taylor, Sir Gordon: The Surgery of the Innominate Artery with Special Reference to Aneurysm. *Brit. J. Surg.*, **37**: 375, 1950.
- 23 Greenough, J.: Operations on Innominate Artery.



- Report of a Successful Ligation. *Arch. Surg.*, 19: 1484, 1929.
- 24 Gross, Robert E.: Treatment of Certain Aortic Coarctations by Homologous Grafts. A Report of Nineteen Cases. *Ann. Surg.*, 134: 753, 1951.
  - 25 Hare, H. A., and C. A. Holder: Some Facts in Regard to Aneurysm of the Aorta. *Am. J. M. Sc.*, 118: 399, 1899.
  - 26 Harrison, P. W., and J. Chandy: A Subclavian Aneurysm Cured by Cellophane Fibrosis. *Ann. Surg.*, 118: 478, 1943.
  - 27 Imai: Ein Dunch Extirpation Geheilte Fall Von Aneurysm der Ant. Anonyma. *Deutsche med. Wchnschr.*, 39: 1147, 1913.
  - 28 Kampmeier, R. H.: Saccular Aneurysm of the Thoracic Aorta. A Clinical Study of 633 Cases. *Ann. Int. Med.*, 12: 624, 1938.
  - 29 Kocher, T.: Textbook of Operative Surgery. Vol. II, The Macmillan Co., 1911. New York.
  - 30 Lam, C. R., and H. H. Aram: Resection of the Descending Thoracic Aorta for Aneurysm. A Report of the Use of a Homograft in a Case and an Experimental Study. *Ann. Surg.*, 134: 743, 1951.
  - 31 Lane, J. D., and E. C. Peirce, III: Endoaneurysmorrhaphy for Spontaneous Innominate Artery Aneurysm. *Surgery*, 30: 709, 1951.
  - 32 Lillienthal, Howard: Case of Mediastinal Thyroid Removed by Transsternal Mediastinotomy. *Surg., Gynec. & Obst.*, 20: 589, 1915.
  - 33 Lindskog, Gustaf E.: The Surgery of the Innominate Artery. *New England J. Med.*, 235: 71, 1946.
  - 34 MacEwen: Quoted by Matas.
  - 35 Matas, Rudolph: Traumatic Aneurysm of the Left Brachial Artery. *Med. News, Philadelphia*, 53: 462, 1888.
  - 36 ———: An Operation for the Radical Cure of Aneurysm Based Upon Arteriorrhaphy. *Ann. Surg.*, 37: 6, 1903.
  - 37 ———: Surgery of the Vascular System. Vol. V, Chapt. LXX, Surgery, Its Principles and Practice. W. B. Saunders Co., 1914, Philadelphia.
  - 38 Meyer, Andre, Olivier Monod, M. Brunel and J. P. Nico and J. M. Dubois de Montreynard: Resection d'un Aneurysme de la Crosse de l'aorte Avec Conservation du Cours du Sang dans le Vaisseau. *Bull. et mém. Soc. méd. d. hop. de Paris*, 64: 278, 1948.
  - 39 Middleman, I. C., and N. W. Drey: Cellophane Wrapping of an Abdominal Aortic Aneurysm. *Surgery*, 29: 890, 1951.
  - 40 Milton, H.: Removal of a Foreign Body from the Bronchus by Intrathoracic Tracheotomy. *Lancet*, 1: 242, 1901.
  - 41 Moore, C. H., and C. Murchison: On a Method of Procuring the Consolidation of Fibrin in Certain Incurable Aneurisms. With the Report of a Case in Which an Aneurism of the Ascending Aorta Was Treated by the Insertion of Wire. (London, 1864), also, *Med.-Chir. Trans.* 47: 129, 1864.
  - 42 Ochsner, Alton: Personal Communication.
  - 43 Page, I. H.: The Production of Persistent Arterial Hypertension by Cellophane Perinephritis. *J. A. M. A.*, 113: 2046, 1939.
  - 44 Pearse, H. E.: Experimental Studies on the Gradual Occlusion of Large Arteries. *Ann. Surg.*, 112: 923, 1940.
  - 45 Poppe, J. K.: Cellophane Treatment of Syphilitic Aneurysms with Report of Results in Six Cases. *Am. Heart J.*, 36: 252, 1948.
  - 46 Poppe, J. K., and H. R. De Oliveira: Treatment of Syphilitic Aneurysms by Cellophane Wrapping. *J. Thoracic Surg.*, 15: 186, 1946.
  - 47 Rundle, F.: Aneurysm of Innominate Artery Treated by Surgery. Report of Three Cases and Records of Twenty-two Cases Collected from Literature. *Brit. J. Surg.*, 25: 172, 1937.
  - 48 Sako, Yoshio, Tague C. Chisholm, K. Alvin Merindino and Richard L. Varco: An Experimental Evaluation of Certain Methods of Suturing the Thoracic Aorta. *Ann. Surg.*, 130: 363, 1949.
  - 49 Sauerbruch, F., and E. D. Shumacker: Technik der Thoraxchirurgie. 1911, Berlin J. Springer.
  - 50 Shumacker, Harris B., Jr.: Surgical Cure of Innominate Aneurysm. Report of a Case with Comments on the Applicability of Surgical Measures. *Surgery*, 22: 729, 1947.
  - 51 Shumacker, Harris B., Jr.: Operative Exposures of the Blood Vessels in the Superior Anterior Mediastinum. *Ann. Surg.*, 127: 464, 1948.
  - 52 Shumacker, Harris B. Jr.: Coarctation and Aneurysm of the Aorta. *Ann. Surg.*, 127: 655, 1948.
  - 53 Swan, Henry, C. Maaske, M. Johnson and R. Grover: Arterial Homografts: II. Resection of Thoracic Aortic Aneurysm Using a Stored Human Arterial Transplant. *Arch. Surg.*, 61: 732, 1950.
  - 54 Temple, L. J.: Aneurysm of the First Part of the Left Subclavian Artery. *J. Thoracic Surg.*, 19: 412, 1950.
  - 55 Tuffier, Th.: Intervention Chirurgicale Directe Pour un Aneurysme de la Crosse de l'Aorte, Ligature du Sac. *La Presse Medicale*, 1: 267, 1902, also, *Bull. Acad. de med., Paris*, 85: 586, 1921.
  - 56 Wilson, Harwell and Duane Carr: Combined Cervical and Thoracic Approach for Resection of Large Arteriovenous Aneurysm. *Surgery*, 24: 342, 1948.
  - 57 Yeager, G. H., and R. A. Cowley: Studies on the Use of Polythene as a Fibrous Tissue Stimulant. *Ann. Surg.*, 128: 509, 1948.